
Welcome to Ames Research Center (1987 Forum on Federal Technology Transfer)

William F. Ballhaus, Jr.

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William F. Ballhaus, Jr., Ames Research Center, Moffett Field, California

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Ames Research Center
Moffett Field, California 94035

INTRODUCTION

This is a transcription of the welcome by William F. Ballhaus, Jr., Director, Ames Research Center, to the Forum on Federal Technology Transfer, at Ames Research Center, September 11, 1987. [Dr. Joseph Longo, in introducing Dr. Ballhaus, noted that he holds the H. Julian Allen Award, the Lawrence Sperry Award, and the Arthur S. Fleming Award, and recently received the Presidential Rank of Meritorious Executive in recognition of his outstanding accomplishments.]

WELCOME TO AMES RESEARCH CENTER

I'd like to tell you a little about Ames Research Center, some of the things we're involved in, and how these tasks have led to the transfer of technology. Technology transfer is one of our most important accomplishments. We're a research and technology center; we have the largest R&D budget of any organization in the Silicon Valley. We're the sixth largest high tech firm in Silicon Valley.

But developing technology is only part of our mission. Unless somebody uses the technology, it's worthless. For example, last night I met with an astronaut who has been in a tank with a new space suit on for the last two days, and with a committee from Space Station that's looking at using that suit for the Space Station. It's a hard suit, a high-pressure suit that eliminates the requirement for free breathing, protects the astronaut from debris hits, and is easy to maintain.

But the process of getting that sort of technology out of the laboratory and into the hands of the people who are actually going to use it is a very difficult one. It takes a lot of nurturing and hand-holding. You've got to bring the users to the incubator and work with them very carefully. So part of our mission is to develop the technology; the other part is to make sure that technology is used effectively. And that's a very, very difficult task.

Let me run through some slides to guide the discussion. First of all, for those of you who aren't familiar with NASA, this shows you where the various NASA centers are located and indicates part of the problem that we have with technology transfer in that we're geographically dispersed. Ames Research Center is in California at two sites, Moffett Field and Edwards Air Force Base. We were the second NASA center founded; we were founded about 1940--there was an interest in developing an aeronautical laboratory on the West Coast because there was a concern that Langley Research Center, the first NASA center, was vulnerable to attack from Europe. So in 1939, Lindbergh and Orville Wright and others selected a site here at Moffett Field for a second aeronautical research laboratory.

Our job is to develop the technology for transfer to the large, manned space-flight centers--to Marshall and Johnson and Kennedy. This is an aerial view of the Moffett site. It's rapidly expanding. We've just built the Fluid Mechanics Lab, the Numerical Aerodynamics Simulator Building, where we are now, and we will begin construction early next year on a human performance research laboratory. We will put in mockups of the Space Station and begin to integrate hardware into those mockups. This is our southern site--the Ames-Dryden Flight Research Facility. You can see hangars and office buildings and, up in the right-hand corner, you can see the Shuttle De-mate Facility where the Shuttle Orbiter is placed back atop the 747 that ferries it to the Cape.

I'd like to quickly describe our mission here in space; it's a rather broad one. We just finished a strategic plan that's going to help us focus a bit more. One of the principal areas that we're going to pursue is humans in space. I approach it from a historical perspective. If you look forward 100 or 200 years and try to anticipate what the history books will say about this small period of time, perhaps they may say that this era was significant because it was that unique point in history when humans changed their status from visitors in space to permanent residents of space. And, by the end of this century, we will have a permanent human presence in space, if we don't have one already. The Russians claim that they are going to permanently man their Mir space station.

So this is a very important period in history from an aerospace perspective. There are many things that we have to do: much technology that has to be developed and a great deal of knowledge that has to be learned before we can place humans in space for long periods of time. The bone demineralization, muscle atrophy, cardiovascular deconditioning, the psychosocial problems--all of these work against a long-term human presence in space. Also, supporting life--if you were to go to Mars, you can't take enough sandwiches to go there and get back a couple of years later. We've got to figure out how to recycle; how to support life in a hostile environment; how to make that life not only healthy, but also as productive as possible. So the human factor comes into it, the human/machine integration.

In any case, that's the first item: trying to make sure that we have a healthy, productive presence in space.

The second item deals with the integration of some disciplines at the center, the combination of which I think is unique to Ames Research Center. These include the use of our aeronautical human factors for applications in space, our command and control expertise, and our expertise in artificial intelligence. We are attempting to combine these in a synergistic way to take an overall system look at a system that has a human in the loop, and to increase the reliability of that system--and to be sure we make that system as human error-tolerant and productive as possible. So we're looking for reliability, for capability, and for productivity.

The third area deals with the origin and evolution of life, on Earth and in the universe. Examples of this research are our research in global biology--in other words monitoring land masses, the oceans, and the atmospheres, and looking at the interaction of those Earth systems to determine what the effects are on Earth's

biology. Also we are looking at the origin of life in the universe, looking at such things as the Murchison meteorite, carbonaceous chondrites, to determine how early complex molecules were formed. We are looking for extraterrestrial intelligence, using sophisticated parallel-processing computers to analyze signals that come from distant sources in the universe to see if there seems to be any "intelligence" in those signals.

The next area deals with developing flying laboratories, orbiting observatories, and interplanetary probes. Another area deals with transatmospheric vehicles. A good example is the Shuttle; much of the upgrading on the thermal protection system on Shuttle were developed here at our ceramics laboratory, and virtually all of the thermal protection system testing was done in the arcjet facilities here at Ames. We're playing a significant role in the aerospace plane--the President's "Orient Express" activity--working in aerothermodynamics and in the thermal protection systems, and we hope to be the responsible test organization when a test vehicle is actually produced.

Finally, we support the Space Shuttle, not only with landing, but also with guidance and control, using our flight simulations and our thermal protection system expertise.

In aeronautics, the first part of our mission is discipline-oriented. It deals with conducting fundamental research in several basic aeronautical disciplines: aerodynamics, fluid dynamics, guidance and control, human factors, and flight testing.

The second area deals with facilities. Ames has a \$2.7 billion facility replacement value. We're probably as "facilitized" as any of the NASA centers, and we've sought over the last 15 years to attain preeminence in four key aeronautical facilities. The first is supercomputers, and in the NAS building we house one of the most powerful supercomputer complexes in the country, the numerical aerodynamics simulator. It's being accessed by about 700 people across the country at 70 remote sites, so there are high-bandwidth terrestrial lines and satellite links into this facility from other NASA centers, from universities, from other federal laboratories, and from industry. In addition to that, we have our own central computer complex, which contains two powerful computers, the Cyber 205 and a Cray XMP.

Another important area is wind tunnels. You saw the large wind tunnel behind you when you came into this building. As far as we know, it's the world's largest wind tunnel. We're just about to complete integrated systems testing on an upgrade to that wind tunnel. We have a variety of wind tunnel complexes at the Center, probably the broadest spectrum of wind tunnel capability in the country, certainly the heaviest in terms of subscription--some of our wind tunnels are booked up well over 2 years in advance.

We also have flight simulators that are used to identify sources of human error or system error in a cockpit or air traffic control situations and then to develop procedures and technology to reduce the potential for those errors. In addition we can get high-fidelity simulations of rotorcraft and powered-lift vehicles and the

Shuttle. One of the advantages we have with our flight testing capability being very close to our flight simulators is that we can work on the simulator, develop a set of control laws that have proper handling qualities from a pilot's standpoint, take the flight box out of the simulator and plug it into the airplane, and go try it--then bring the pilot back into the simulator to prove the fidelity of the simulation based experience, modify the control laws, and apply it all to flying the airplane.

The final area deals with flight testing. With the Moffett site and the site at Dryden, we have a very powerful national flight test capability. We have responsibility for rotorcraft, helicopters, and tilt-rotors; for powered-lift vehicles, harriers, and advanced short-takeoff/vertical-landing aircraft; and for high-speed vehicles.

I'd like to review two or three of our current activities to give you the flavor of some of the things we do. The first, the Numerical Aeronautical Simulator, is a balanced computational system. It has a number of subsystems, supercomputers. We have a Cray 2 with a 256-million-word memory. We're now negotiating with Cray and with ETA Systems to put two additional supercomputers in the system. We'll test those systems and then upgrade the most capable so that a year from now we will have a machine as the principal high-speed processor in the system that's about four times more powerful than the Cray 2. It is remotely accessible, as I mentioned earlier, and it tries to create an overall environment for a researcher, for an aerodynamicist, or for a chemist that is highly productive.

When I was doing this kind of research about 10 years ago, we used to stay up all night in the computer center and do many runs and get large tables of numbers, and then sit down the next day and try to plot them with a French curve and make some sense out of them. Well, we're much more advanced than that today. You probably noticed some of the pictures as you walked in. We have very sophisticated dynamic and color graphics where you can look at an aerodynamic flow field and zoom in on it, you can rotate it, you can really examine and understand the physics--and thereby improve the engineering and design of the vehicle. That was very difficult to do 10 years ago.

Just to give you a flavor of what's to come, our human factors people are working on a telepresence capability that puts you in a virtual environment. For example, you can put helmets on pilots and you put them in a virtual environment where they don't really have to see what's going on outside. They can integrate data from a number of different sensors and make sense out of them and take appropriate actions. We're experimenting with a helmet like one you would use in the construction of Space Station, where you have sensors on your hands and you have controls in the helmet and it basically puts you in a virtual environment. You could be at the Space Station but you're really sitting on Earth, or perhaps you could "be" inside the Space Station. You could go out and work your way along the side of the Space Station, unscrew a plate and put on another one--that's what we mean by telepresence.

Our human factors people were experimenting recently with trying to do that for a fluid dynamic flow field, one that we've been very interested in; that is, one inside the turnaround ducts of the Space Shuttle main engine, a very complicated three-dimensional flow. So they put the fluid dynamicist in a virtual environment of that flow field, where a person can actually swim around in it--you can study turbulence, or you can study vortices that are shed, you can look at where you get secondary flows--it gives you a sense of the physics that you find very difficult to get from line plots. That's something that makes a more natural interface for the human trying to improve the engineering design of the system.

This figure shows some of the elements in this building: the integrated support processing complex, a number of mid-level computers that help move data bases around and control them. The Cray 2 is shown at the top left, then here is the building when it was under construction, and in the lower right is a work station. The flow field you see is the flow inside a rotor-stator system in a jet engine.

The objective of the numerical aerodynamics simulator program is to provide an operational capability for advancements in aerodynamics, in fluid dynamics, and in other related disciplines of interest to NASA.

The uses of the NAS system are broad; from fundamental studies of turbulence to the development of new aerodynamic concepts--creating new flight vehicle concepts, analyzing the O-ring and the structure on the solid rocket motor for the Shuttle, looking at different things for Space Station, computing reaction rates for chemical reactions, and looking at atmospheric simulations. Some people are doing research on the AIDS virus from a chemical standpoint, and again, using computational chemistry, some people are looking at superconductors. So there are many, many things you can do with computational modeling (which we wouldn't have thought of, say, 10 years ago) that can now be done because we have this new, powerful capability. I think that can only continue in the future. Our modeling capability improves yearly.

The second aspect of the facility really deals with its pathfinder objective; that is, it is intended to keep this country at the leading edge in computationally related disciplines. So, for example, the operating systems that we use here we're pioneering--I think this is the first complex that used UNIX as an operating system throughout its entire complex of computers from the work station all the way up to the supercomputer. And it was instrumental, I think, in encouraging Cray to support UNIX and the other supercomputer vendors to support UNIX. We committed to that decision a long time ago when it was a high-risk decision, and it turned out in retrospect to be the right decision. We pioneered the use of graphics for a number of engineering applications; for example, remote communications (there are many advances that are being made because of the development of this new system). And then those advances get replicated in other computer centers around the country.

Boeing, for example, is a company that doesn't like to rely on NASA or anybody else to provide a facility that they need for their next product. They rely on us for research, they'll take our computer codes, they'll do research testing in our wind tunnels, but they really don't want to have to rely on anybody else for production of a product. The other aircraft companies are not like that, but Boeing is in

a unique position because of their financial position. In any case, the way they use our facility is for the advanced research in their computational simulations, but also they send their computer people down here to look at what's in the system and then they take it back to Boeing and replicate it. So they try to build up, to follow what's going on here--let us take the risks and then, if a procedure works, they can incorporate it in their operational system.

This picture I'm showing you now may not turn many of you on, but for somebody who tried to do this for many years, it was tremendously exciting to be able to see something like this. This is an F16 at angle of attack. These are particle traces on the surface and just off the surface on the forward part of the fuselage. By numerically injecting dye in the flow, you can follow the particle path throughout the flow field. If you look carefully, you can see vortices shed off the strake in front and another set of vortices shed off the leading edge, and they interact. I was talking to somebody from Holland yesterday, the head of the national aeronautics laboratory, and we both remembered a movie we saw that was made in France about 15 years ago. It showed what happens to the flow over a wing at high angle of attack, and the French had made a beautiful movie with dye injection to show the flow patterns. The surface of the wing--that red patch that you see--looks exactly like what we saw in the movie. So now we can actually compute what we used to be able to do only experimentally, and even then with some difficulty. This is a tremendous step forward to include the viscous effects in the flow and much more of the physics than we were able to get before. It has many applications.

Here is a chart I've used in a couple of papers that really describes some of the motivation behind the use of a computational approach. It plots relative computation costs versus time in years. There are two plots; the one on the left is the reduction in the cost of doing a given computation due solely to the introduction of new computer systems. You can see that as new computers have become available, from the IBM 650 all the way to the Iliac 4, the Cray 1, Cyber 205, the Cray 2, the NAS system--you can see that there's been a fairly substantial improvement in the efficiency of doing a given computation. Now the mathematics of the problem hasn't stood still. The improvements in numerical solution algorithms, computational mathematics; those improvements have reduced the cost at about the same rate. You see the slopes of the two curves are about the same. Notice that those are orders of magnitude--they're log charts we're dealing with here. So we're looking at 10^5 reduction--about a factor of 100,000 reduction--in the cost of doing a given computation in the last 15 years.

Just to put that in perspective, if today we can do the flow field you saw in the previous figure, the flow past an F15, it takes maybe an hour or two hours on a Cray 2, which is expensive. It takes a lot of time--it's maybe a couple of thousand dollars when we first start out. A few years from now we'll be able to do it for \$100. If you were to have attempted that computation back in the early 1960s on the computers available at that time with the mathematics available at that time, you'd still be waiting to get your output, because it would take about 35 years to get one answer, and the cost would be over \$1 billion. Of course it's not feasible to do a calculation like that because of mean time between failure and so forth and the fast

turnaround that's required. We find that an aerodynamicist or a researcher wants a turnaround of several a day. In other words, if it takes more than an hour to get a result, the researcher will go somewhere else to try to solve the problem. So the advances that we've seen in speed have translated into advances in terms of reduction in costs, and that's really motivated much of the progress that we've seen in computational systems and in computational analysis.

This is an example. I wish I could show you the movie that goes with this because there are beautiful dynamics inside this part of the Space Shuttle main engine. We were able to analyze it and for the first time understand what the flow field looks like in the main engine. It's very difficult to find that out experimentally. And one of the things we found was that the central transfer duct really was worthless. It carried only 9% of the flow and there were large regions of secondary flow throughout this turning duct. So, working with people at Rocketdyne and at Marshall Space Flight Center, we provided the computer code and they were able to redesign it, eliminating one of the transfer ducts and improving the head losses by about 45% through the entire flow.

The next area I'd like to talk about is artificial intelligence. That's a topic almost everybody has an opinion on. We're trying to do a couple of things here. One is to develop a core capability of research talent that can be brought to bear on the Agency's problems in automation and robotics, and that's been difficult for NASA to do. The salaries that experts in artificial intelligence are attracting now are well beyond the civil service scale. Fortunately, we've been able to attract a few people who got their Ph.D.s a few years ago, went out, started companies, made their fortune, and now want to do things that are fun, so they want to work on Space Station. We're building up a corps of such people who have the experience, and we've probably been able to attract by far the best expertise in NASA in artificial intelligence. We're developing a strong core capability, but that's only half of the battle.

The next step is to make sure somebody uses this expertise, so we've outlined a number of demonstrations at the user sites where we'll actually integrate automation technology into engineering test beds and give the people who are going to develop Space Station and other NASA projects experience in the use of this new technology.

We now have a demonstration going on at Johnson Space Center with the thermal control system for the Space Station. That's in engineering test and thermal-vac chamber. What we're trying to do is introduce as much automation technology as possible to be incorporated in the final design. The intent, then, is to relieve the astronauts of a tremendous amount of housekeeping that they would otherwise have to do and make their time on station much more productive.

Next we will do a demonstration of the power system at Lewis Research Center in Cleveland. They have responsibility for developing the power system; our job, again, is to introduce high levels of automation into that. Then the next step is to integrate the two domains, the power system and the thermal system.

Well, this describes some of the research areas at the Center, such things as scheduling and planning, human-machine interface, knowledge acquisition and learning, machine learning, architectures, large sparse distributed memories, and so forth. Our research here in artificial intelligence is guided very strongly by the applications of interest to NASA. Now, coupled with this, as I mentioned before, is our human factors activity, and that's one of the ways in which our capability here I think is unique. We have the expertise now to work the automation part of it; we can now put the human in the loop and look at the effectiveness of the overall system.

Here's a cartoon that shows you the kinds of things that robots will be doing in the future. They'll be servicing satellites, perhaps even constructing large structures in space. There are a number of research efforts under way right now to have robots do these kinds of simple things and cooperate with each other in the task. For example, to make two robots go off and pick something up, carry it somewhere, and have them cooperate is an interesting research task.

Another area I'd like to cover very quickly is not really a new concept; it's a concept we experimented with a number of years ago, but concepts like this--radical departures from existing technology--take a long time to integrate into our operational fleet. This is the tilt-rotor concept, the XV15. We started working with tilt rotors a long time ago with the XV3, never really made it work right, but using our computers, our wind tunnels, our flight simulators, and then ultimately a flight-demonstration vehicle, we've been able to demonstrate that the tilt-rotor concept does work.

Here's a sequence of pictures: This shows the XV15 in its vertical takeoff mode, then in transition as the nacelles tip down, and then becomes a conventional turboprop type aircraft. With this approach, you can maintain very near to the hover efficiency that you get with a conventional helicopter and yet you can double the forward flight speed of the conventional helicopter. You substantially reduce the vibration and the noise, and the maintainability problem is reduced substantially.

You can imagine what something like this could do on the East Coast. In fact, we've been involved in studies with the DoD and the FAA and the New York Port Authority, looking at how a tilt rotor in a civil version would perform in that area; we've been working with people in Alaska to see how it would perform in Alaska. It turns out that if you have a flight that's on the order of 300 miles or less, this is usually much more efficient than driving to your local airport, hopping on a 727 and flying somewhere. The tilt-rotor can take off and land vertically so you don't need long runways.

Here is a good example. Look at the extent of the runways--all the real estate you eat up by doing that. You can't do that in very many places, so you have these large hubs that are now becoming overcrowded. In New York and New Jersey, for example, you could take a tilt rotor and land right on a pier. In fact, you could land a number of them on a single pier, flying right down over the river. Commuting time would be reduced substantially. This is the heliport--tilt rotors come in and

you can see a number of them have landed here, and that's a hub. Then people can get on larger aircraft and fly to China or Japan or wherever they're going.

Well, those are just a few areas we've worked in, as examples. We do produce a tremendous amount of technology here. One of the difficulties is disseminating that technology. There are a number of ways in which we do that, but there is the charter that mandates us to do that, the Space Act of 1958 which charges us to "provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof." Because of this, NASA has been an open organization. We probably publish 750 papers a year at this site, and we interact very closely with industry and people in universities. We have interactions with over 200 colleges and universities and a number of industrial co-venturers.

The Office of Commercial Programs of NASA has two objectives: (1) to establish a close working relationship with the private sector and academia to encourage investment in and the use of space technology, and (2) to facilitate private sector space activities through the use of available government capabilities. I've mentioned our large facilities base here and that it is used quite extensively by industry.

This is a schematic that shows the flow in the process. Our principal method of dissemination is by publication--we publish a tremendous number of papers. The next most effective form is through people. Our people present papers, they interact with people from industry at conferences, a tremendous amount of technology gets transferred on the back of a bar napkin. That informal process seems to be the most effective. We have a program here called Industry Research Associate Program where if we have a joint interest in a particular project, industry will send somebody here at their expense; we'll provide computer time or wind tunnel time and office space and we'll work jointly on the problem. What that does is leverage our manpower and give us a larger manpower base with which to conduct our research. We've found that it's really the most effective means of technology transfer.

Here's a good example: In 1975 some people from Rockwell came here and they were desperate. They wanted time in the wind tunnel to solve a problem in an aerodynamic development. Our wind tunnel people looked at their need and said, "Look, we cannot solve the problem that you have in the time that's available on your schedule. Why don't you try a computational approach?" (One of the key ingredients in technology transfer is desperation.) And these people were desperate; they knew their program was going to fail if they didn't get the problem solved, and they were willing . . . desperate enough to try a new technology. So they sent a person to Ames to work with us for about a month, to learn how our computer code worked, to modify the computer code to meet their particular geometrical requirements, to run several test cases, and then to take the result back and teach their designers how to use it.

Now in that process what happened? Number 1, our computer code got recognition because it saved a program, and that was the first evidence of payoff in the massive investment that NASA had made in computational fluid dynamics for the previous 6-year period. It was a milestone. From the company standpoint, they now had a new

technology that they could use in their arsenal for aerodynamic design. They now had a company expert who was trained in the use of that technology, who then seeded the company by training other people in the company. That's a device we use quite effectively to transfer our technology.

Then the final way in which we transfer technology is through products. Two examples: This is a device that's used to test stiffness in bone, which is useful in trying to detect bone disease. We're interested in it from the standpoint of osteoporosis that occurs in space. When the astronauts go into space, their bones demineralize. In fact, we've done measurements on the heel bones of astronauts and of cosmonauts, and we find that the loss continues linearly. In a 150-day mission, you lose about 15% of the density in the heel bone and other gravity-resisting parts of the skeleton.

As time goes on, we don't know whether the loss levels off or continues without bound. So the body adapts very rapidly to the zero-G environment. There's no problem so long as the persons stay in space. When you bring them back they may be subject to fractures; their bones become very brittle and not dense, so there are potential problems with bringing people back.

What we're trying to do is to find ways that we can counter those effects, through regimens of exercise. The cosmonauts do about 2 hours of exercise a day. That's great, but it eats into their productivity. We'd like to have them doing things more efficiently when it costs about \$80,000 an hour to have somebody up there. Another thing they do is wear bungee cords that put stress on the skeleton. So they try all these little "band-aids" to try to fix the problem, and yet they come back severely deconditioned. When the cosmonauts came back from their record 237-day mission, one was unconscious and two couldn't stand for a long period of time, and it was months before they fully recovered. So we have to develop countermeasures. This is one way we can test the effects of disuse on bone. So, for example, on Earth we put people to bed for long periods of time, we stimulate the muscles electrically, we test the stiffness in the bone to see how the body is degrading with time, and then we test countermeasures to try to retard that effect.

Now this was actually developed as a product and marketed in cooperation with a company. You can see the medical benefits of being able to test the stiffness of bone by vibrating it.

Another example, I think, was a real accident. We developed a compound that was used for a membrane in a life-support system, and somehow it got used to coat the visors on space suits so that they don't scratch. (The visors scratch very easily because the astronauts are always opening or closing them as they face the sun or face away from the sun.) It turns out that putting this coating on the surface reduces the degree to which the helmets get scratched by about a factor of 10. Foster Grant decided to use the membrane on sunglasses and, in fact, I think this has been one of the most successful examples of marketing a NASA-developed product in an area that's unrelated to aerospace. They've sold over \$75 million worth of these sunglasses.

Every year we compile a list and description of some of the spinoffs from the space program. The book is called Spinoff and it's kind of fun to read through it every year and see the use of portable X-ray machines to look for injuries in accident victims and football players--all the many things that come out of technology for aerospace applications.

Now, if there are questions, I'd be glad to try to answer.

Q. A pressing problem is combustion, whether in automobiles or fluidized beds. Have you people been approached to do any modeling in that area?

A. We've done a little bit. The primary role for propulsion in NASA is at the Lewis Research Center in Cleveland. We've supported them somewhat because of our computational fluid dynamics expertise and our computational chemistry expertise. We've also worked to some degree with the people at the Combustion Research Facility at Sandia. It hasn't been a major role for us, but some of the technologies that we've developed are applicable, and certainly the computational technologies are applicable. So we have sort of a peripheral interest in that, not a main line interest. There are a number of people here that are very interested in that discipline.

Q. It's very clear to all of us that NASA is doing a very good job in technology transfer. I'd like to know if you can tell me what percentage of NASA's operating budget is devoted to such activity.

A. No, I can't. Anyone from headquarters know the answer to that question?

[Another voice] Probably \$18 million a year.

Q. Can you comment on the extent of activities you plan to engage in in superconductors research?

A. Yes, Ames Research Center isn't doing anything other than to provide this facility here (the numerical aerodynamics simulator) to people in other parts of the country who are doing that. People at Lewis Research Center in Cleveland are doing some experimenting with superconducting. We don't really have a strong role in that type of materials research at this Center.

Q. To the extent that they are separable, what percentage of the work here is involved in aeronautical activities and what percentage in space science?

A. OK, it's about 60-40 in favor of aeronautics, and the space side includes space technology as well as space science, life science, and earth science.

Q. About the Foster Grant deal, did they pay royalties, and if so, what policies do you use for accepting them?

A. I understand that they did pay royalties, and, Larry, perhaps you'd like to comment on what the policies are.

Larry Milov: I think there've been some recent changes in that, but they did license the process and a percentage of the royalties are paid back to NASA. We've agreed to change the percentage of the royalties that go back to the inventor as a part of the new law.



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